ECONOMIC IMPLICATIONS OF ROUGHAGE AND GRAIN SUBSTITUTION IN BEEF CATTLE WINTERING RATIONS

by

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INTRODUCTION

Many farms in the Great Plains are large and a relatively high percentage of the land is used to grow so called "fattening" grains compared with the average used for high protein grans and roughages. The fattening grains include corn, milo, and barley. The high protein crops include oats and alfalfa. This results in a substantial surplus of fattening grains over the quantity needed to fatten cattle.[1] Cattle feeders in the Great Plains feed part of the surplus grain, together with a considerable quantity of roughage to stocker and feeder calves that have been raised in the southern or western farm pastures.

The economic efficiency of feeding grain concentrates to stocker cattle warrants serious study in Kansas as beef is a leading source of income and there is an abundant supply of grain. The inventory of cattle in Kansas is eight percent higher in 1966 than the 1960-1964 average. Feed costs in cattle rations constitute from seventy-to ninety percent of the total cost of production. Any steps toward improved efficiency of the cattle ration will make important contributions to individual farmers and the consumer economy.

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[1] A. G. Nelson, _Relation of Feed Consumed to Food Products in Cattle Feeding_, USDA Technical Bulletin 900, Sept. 1945, p. 2.

There are a number of questions concerning the wintering of cattle in those areas where grain is in surplus. In the first place, market demand for high quality beef has necessitated a reasonable degree of finish and secondly, financial considerations require the production of acceptable carcasses with a minimum use of expensive feeds.[2]

Even though acreage in grain crops is increasing, Kansas remains productive in forage crops. Forage is an integral part of the crop and farm organization on soils in the Great Plains. Grasses and legumes can contribute to an efficient agriculture in two ways: First, they have indirect value in increasing crop yields due to fertility and conservation effects. Second, they have a direct value as a primary crop which can be used in producing a secondary product as livestock.

With the upsurge in cattle feeding in the Great Plains area, together with the abundant supply of grain and roughage, cattle producers have expressed a need for a better understanding of the economic relationships of roughage and grain equivalents in beef production. The purpose of this study is to examine physical relationships of different wintering rations and determine the least cost combinations of rations used in wintering cattle. Thus the research deals with the economic implications of the physical relationships of different feeds and their utilization. The basic relationships are expressed in the form of production functions.

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[2] W. H. Black, et al, Fattening Steers on Milo in the Southern Great Plains, USDA Technical Bulletin 847, April, 1943, p. 2.

There are, of course, as many feed-meat production functions as there are classes and capacities of livestock.[3] A certain quantity of livestock can be produced with many roughage-grain combinations. To complicate the research, beef can be produced with forages alone and, hence unless the price relationships are favorable, the use of grain may be found economically dependent on the variables of time, quality, price of grain, and price of beef.

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[3] Earl O. Heady, Economics of Agricultural Production and Resource Use. (New Jersey: Prentice-Hall, 1957), p. 72.

CHAPTER I

STATEMENT OF THE PROBLEM

The problem this study attempts to solve is: what combination of roughage and grain should be used in economically wintering feeder steers? Results of the research apply to only a limited interval in the growth range of a beef steer, i.e., from 450 to 700 pounds.

CHAPTER II

SOURCE AND CHARACTERISTICS OF THE DATA

The data include information from thirty-nine separate Animal Husbandry feeding experiments at Kansas State University obtained from feeding records and from Feeders' Day Progress Reports covering the period from 1948 to 1958.[4]

The feeds were converted to a standard hay or grain equivalent based on the nutritive value of corn placed at 100 percent. These equivalents were derived from those used in previous attempts to analyze beef production functions.

TABLE 1

RELATIVE FEEDING VALUES OF A POUND OF FEED[a]

Grains	Percent
1. Corn	100
2. Grain Sorghum	95
3. Barley	88
4. Oats	85

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[4] Annual Livestock Feeders' Day Progress Reports, Kansas Agricultural Experiment Station Circulars, (36th Annual Report through the 45th Annual Report), May, 1949 through May, 1958.

5.	Wheat	105
6.	Bran	84
7.	Shorts	84
8.	Molasses Feed	76
9.	Black Strap Molasses	67
10.	Sweet Lassie	100
11.	Tarkio	100

Roughages

1. Silage dry equivalent = 30% of total wet weight in pounds.
2. Hay dry equivalent = Given in dry weight in pounds.
3. Total dry roughage = Silage dry equivalent plus hay dry equivalent.

Table 2 shows the data from Feeders' Day Reports 1948 through 1958 used in this research. The lot number is a number assigned by the Agricultural Economics Department of Kansas State University for this study. The actual gain per head per day for the respective lot number and feeding period is given in Column 4 of Table 2. The final column indicates

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[a] Bob Newsome, Economics of Different Levels for Wintering Steer Calves, An Unpublished Report for Credit in Agricultural Economics Problem, Kansas State University, Manhattan, Kansas, Fall, 1960.

TABLE 2

DAILY GRAIN AND ROUGHAGE EQUIVALENTS FOR ACTUAL GAIN PER HEAD PER DAY AND CALCULATED GAIN PER HEAD PER DAY FOR THIRTY NINE LOTS STUDIED

Progress report year	Page	Lot no.	Actual daily gain per head	Grain equivalent daily	Total dry roughage daily	Calculated gain per head per day
1948-49	27	1	.96	0.00	8.24	.777
"	"	2	.36	0.00	9.18	.802
"	"	3	.39	0.00	11.31	.910
"	"	4	.76	0.00	8.93	.807
"	"	5	.70	0.00	10.14	.831
1949-50	13	11	1.13	0.00	8.47	.840
"	"	12	1.11	0.00	12.24	.906
"	"	13	1.32	2.00	10.84	1.782
"	"	14	1.56	4.00	9.83	1.548
1950-51	28	20	.96	0.00	8.70	.789
"	"	21	.98	0.00	12.25	.907
"	"	22	1.13	2.00	10.95	1.241
"	"	23	1.55	4.00	9.00	1.604
1951-52	32	40	1.22	1.90	11.18	1.466
"	"	41	1.50	3.80	10.49	1.485
"	"	42	.75	0.00	8.50	.783
"	"	43	1.05	0.00	12.93	.935

TABLE 2 - CONTINUED

DAILY GRAIN AND ROUGHAGE EQUIVALENTS FOR ACTUAL GAIN PER HEAD PER DAY AND CALCULATED GAIN PER HEAD PER DAY FOR THIRTY NINE LOTS STUDIED

Progress report year	Page	Lot no.	Actual daily gain per head	Grain equivalent daily	Total dry roughage daily	Calculated gain per head per day
1952-53	24	50	.66	0.00	6.25	.736
"	"	51	.96	0.00	11.27	.869
"	"	52	1.22	1.90	10.80	1.227
"	"	53	1.37	3.80	10.91	1.854
1953-54	11	60	2.05	5.07	7.59	1.345
"	"	62	2.09	5.08	7.97	1.332
"	4	62A	.97	0.00	13.36	.854
1954-55	54	70	1.92	3.80	8.72	1.597
"	"	71	1.84	3.80	8.71	1.598
"	58	72	.90	0.00	12.11	.901
1955-56	8	80	.91	0.00	12.11	.901
"	21	81	1.79	3.70	8.91	1.566
"	56	82	1.81	3.80	8.71	1.597
1956-57	47	90	1.60	4.22	7.68	1.475
"	49	91	1.77	3.80	8.94	1.589

TABLE 2 - CONCLUDED

DAILY GRAIN AND ROUGHAGE EQUIVALENTS FOR ACTUAL GAIN PER HEAD PER DAY AND CALCULATED GAIN PER HEAD PER DAY FOR THIRTY NINE LOTS STUDIED

Progress report year	Page	Lot no.	Actual daily gain per head	Grain equivalent daily	Total dry roughage daily	Calculated gain per head per day
1957-58	40	101	1.41	4.56	7.50	1.802
"	47	103	1.46	3.86	10.83	1.471
"	49	104	1.68	4.56	7.47	1.802
"	65	106	2.05	4.75	7.76	1.802
"	"	107	1.96	5.00	7.28	1.881
"	"	108	2.00	4.75	7.31	1.844
"	"	109	1.88	4.75	7.34	1.841

the calculated average daily gain per head from the regression equation derived from this research.

Data from feeding records for twenty-one lots used for 50-pound weight interval analysis are in Appendix Table 1. This part of the study did not produce conclusive results, but is presented as a matter of interest. Table 3 shows the actual hay equivalent and grain equivalent in the twenty-one lots studied in the respective fifty pound gain intervals. These hay equivalents and grain equivalents were computed from information listed in Appendix Table 2 showing the total hay equivalent for the fifty pound production intervals, the hay equivalent per one pound of beef gain, the total grain equivalent for fifty pound production interval, and the grain equivalent per pound of beef gain. Table 3 indicates the respective weight intervals in relation to progressive increases in roughage equivalent usage. Information from Table 3 is plotted in Figures 1 through Figure 6.

TABLE 3

HAY EQUIVALENT AND GRAIN EQUIVALENT IN RELATION TO WEIGHT INTERVALS

400-450 Pounds		450-500 Pounds	
Hay Equivalent	Grain Equivalent	Hay Equivalent	Grain Equivalent
153.0	83.0	160.0	161.5
155.5	85.0	160.5	147.5
224.0	0	245.5	115.0
228.5	0	250.0	96.5
248.0	110.0	253.5	119.0
252.5	0	280.0	121.0
260.5	0	377.0	139.0
278.5	145.0	388.5	66.5
297.0	106.0	390.0	0
342.5	0	402.0	0
360.0	0	404.0	0
401.0	75.7	406.5	69.0
450.5	96.5	475.0	0
463.3	0	482.5	0
516.0	0	500.0	0
574.0	0	624.0	0

TABLE 3 - CONTINUED

HAY EQUIVALENT AND GRAIN EQUIVALENT IN RELATION TO WEIGHT INTERVALS

400-450 Pounds		450-500 Pounds	
Hay Equivalent	Grain Equivalent	Hay Equivalent	Grain Equivalent
581.2	0	1090.0	0
		1095.0	0
		1145.0	0

500-550 Pounds		550-600 Pounds	
Hay Equivalent	Grain Equivalent	Hay Equivalent	Grain Equivalent
197.0	78.5	184.5	112.5
211.0	107.0	191.5	115.0
219.5	126.0	194.5	117.5
221.5	127.5	225.0	130.0
237.0	147.0	300.0	127.0
332.0	193.5	306.5	122.0
367.5	137.5	376.0	152.5
375.0	70.0	426.5	75.0
424.0	0	470.0	0

TABLE 3 - CONCLUDED

HAY EQUIVALENT AND GRAIN EQUIVALENT IN RELATION TO WEIGHT INTERVALS

500-550 Pounds		550-600 Pounds	
Hay Equivalent	Grain Equivalent	Hay Equivalent	Grain Equivalent
536.0	87.7	697.0	201.5
653.5	0		
732.0	0		
966.5	0		
1221.5	0		

600-650 Pounds		650-700 Pounds	
Hay Equivalent	Grain Equivalent	Hay Equivalent	Grain Equivalent
222.0	152.5	218.0	23.5
277.0	152.0	369.0	192.0
300.0	97.0	487.5	71.5
338.0	133.0		
369.0	192.0		
452.5	157.0		

FIG. 1

Amounts of Grain and Hay Used in Twenty-one Lots to Produce Four Hundred Fifty Pounds of Beef

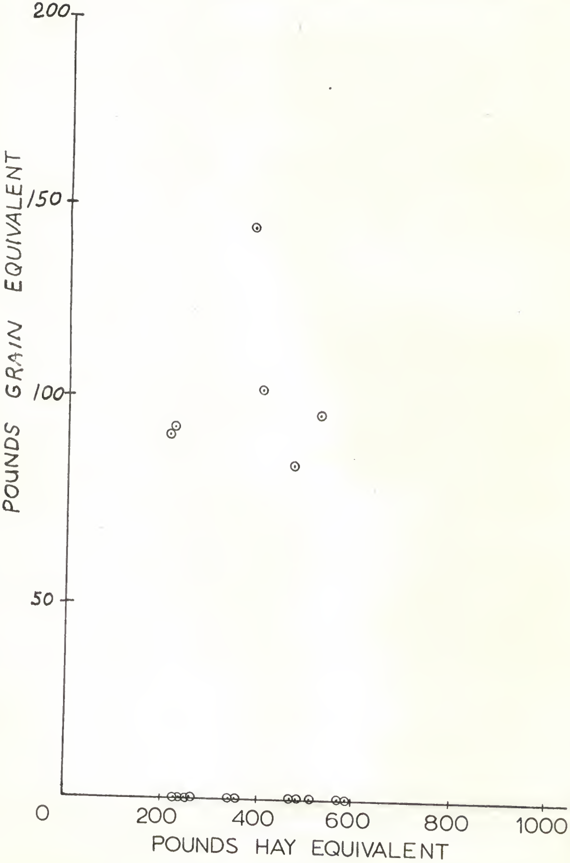


FIG. 2

Amounts of Grain and Hay Used in Twenty-one Lots to Produce Five Hundred Pounds of Beef

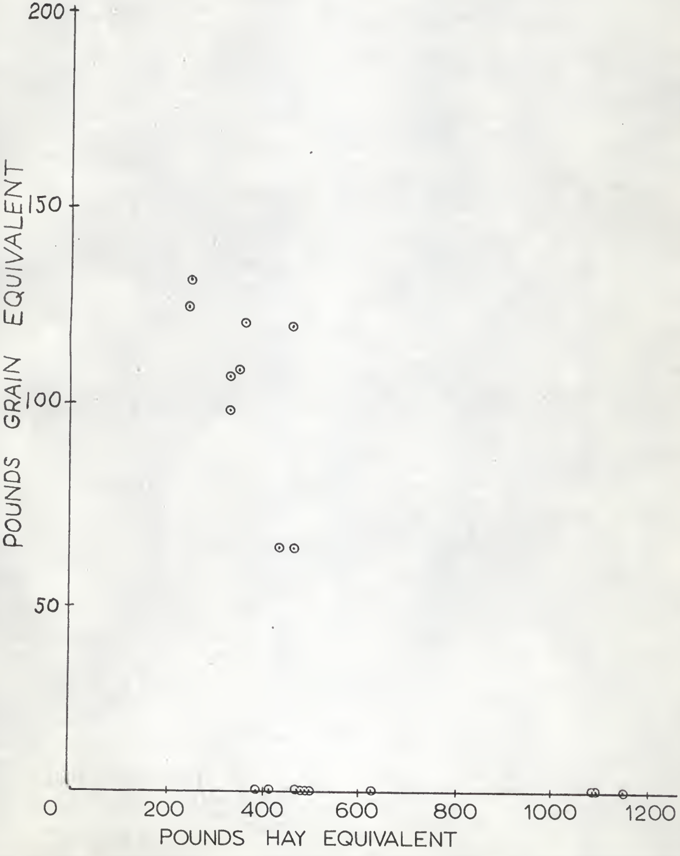


FIG. 3

Amounts of Grain and Hay Used in Twenty-one Lots to Produce Five Hundred Fifty Pounds of Beef

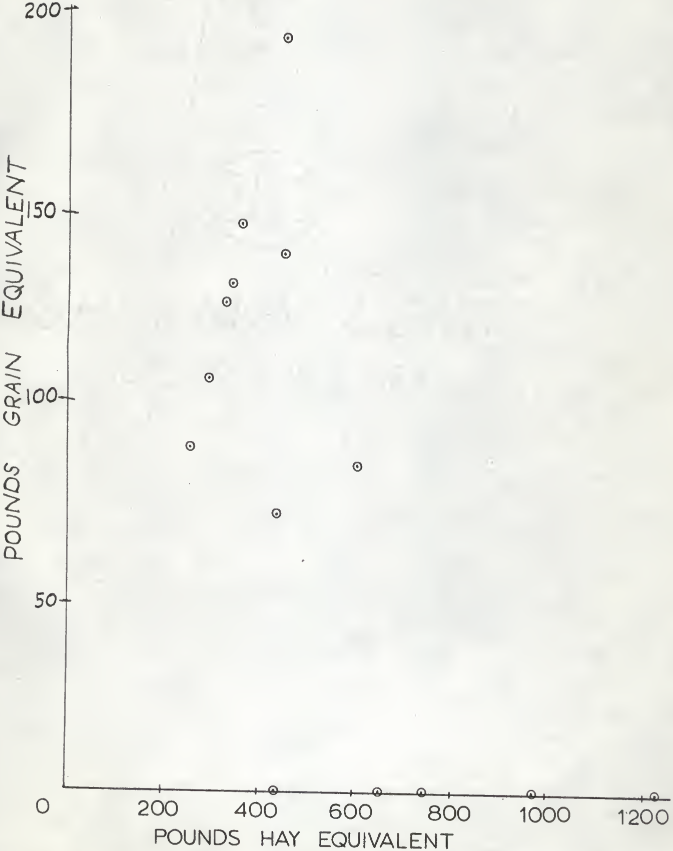


FIG. 4

Amounts of Grain and Hay Used in Twenty-one Lots to Produce SIX Hundred Pounds of Beef

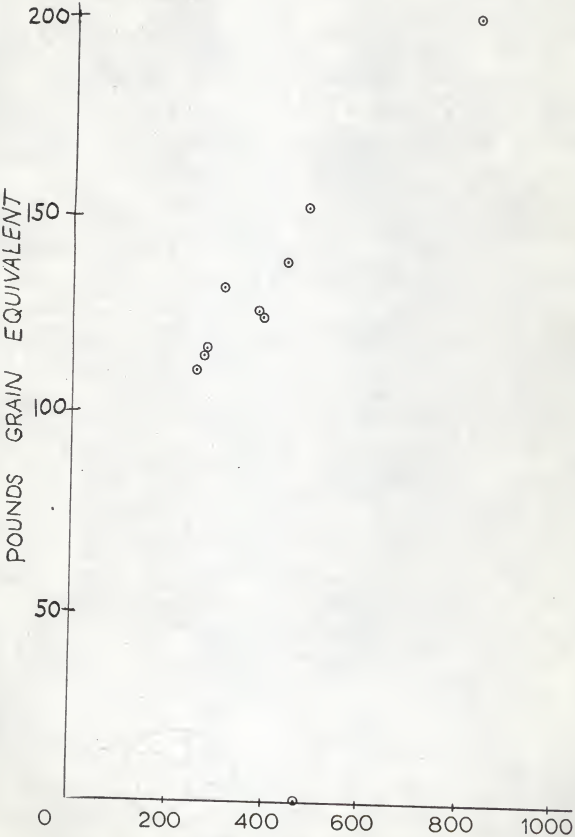


FIG. 5

Amounts of Grain and Hay Used in Twenty-one Lots to Produce Six Hundred Fifty Pounds of Beef

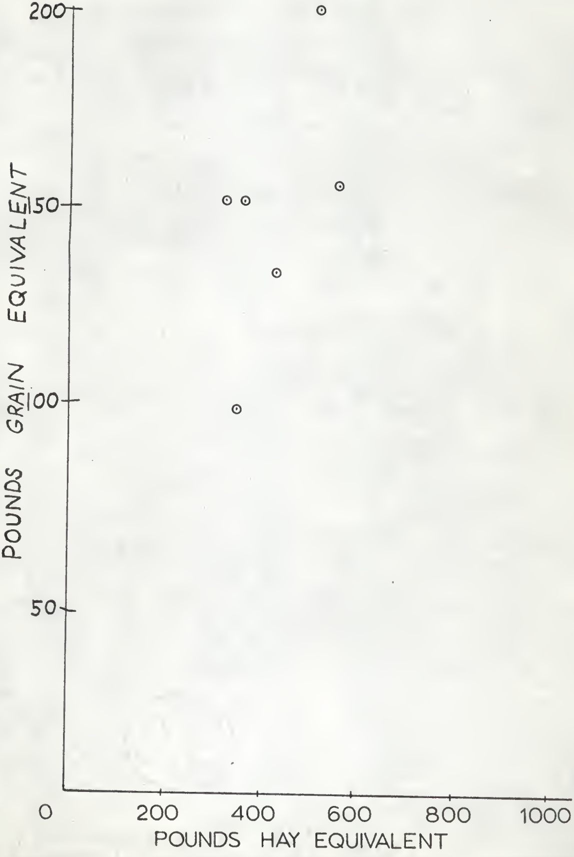
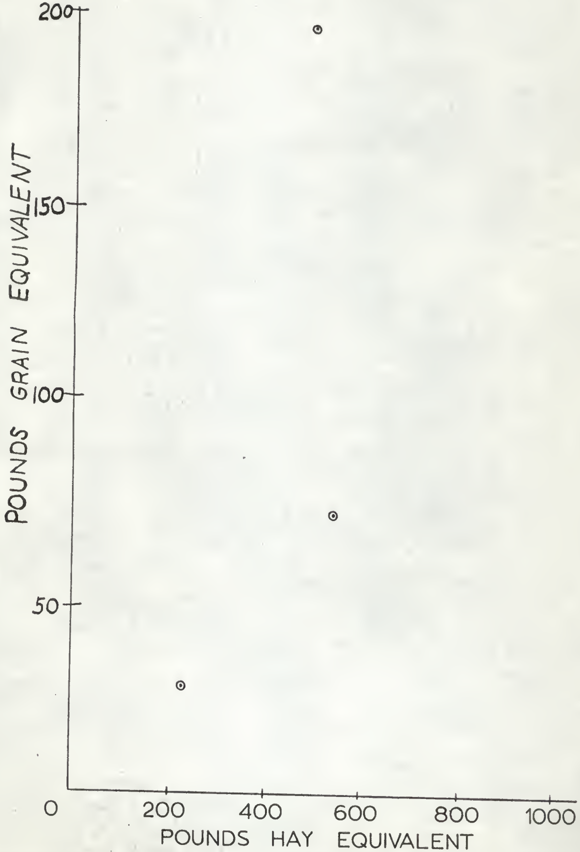


FIG. 6

Amounts of Grain and Hay Used in Twenty-one Lots to Produce Seven Hundred Pounds of Beef



TESTS OF SIGNIFICANCE ON EXPERIMENTAL DATA

Statistical tests were computed to determine whether year to year variation had an effect on output. Specifically, it was necessary to know if the different years had any significant effects on the rate of gain.

The mathematical model used is as follows:[5]

1. $Y = \bar{y} + b_{y1.2}(x_1 - \bar{x}_1) + b_{y2.1}(x_2 - \bar{x}_2)$

Where:

Y is the estimated value of specific Y, daily gain in pounds, given values for x_1 and x_2,

$\bar{y}$ is the constant value intercept point on Y axis,

$b_{y1.2}$ is the partial regression coefficient of Y on x_1 independent of x_2, representing X_1 or grain equivalent in pounds,

$b_{y2.1}$ is the partial regression coefficient of Y on x_2 independent of x_1, representing X_2 or hay equivalent in pounds.

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[5] George W. Snedecor, Statistical Methods, (Ames: Iowa State University, 1956), p. 417.

This plane was fitted to the observed points by the method of least squares. This method, generally used in statistical analysis states that the sum of squares of vertical distances from the regression plane to the observed points shall be a minimum. The procedure of least squares computation is shown in Appendix II.

To summarize, statistically years have no effect on the rate of gain over the ten year period chosen in this study. The regression equation indicates that the amount of daily gain (Y) increased an average of .1775 pounds for each pound of grain equivalent and decreased -.0176 pounds for each pound of roughage equivalent consumed. This analysis is based on daily gain for the entire feeding period.

Since it is not logical for the use of roughage to be associated with negative gain, the significance of the -.0176, i.e., the regression coefficient for X_2 (roughage) was tested by use of the "t" test. The procedure for using the "t" test is shown in Appendix II. It was concluded that the rate of daily gain on these beef cattle depended on the amount of grain fed in their wintering ration. This statistical result is derived from the physical input-output relationship and not on a comparison of relative costs of grain and forage. The "t" test indicated the probability is less than .001 for the -.0176 coefficient to have significant effects.

QUALIFICATION OF DATA

In the thirty-nine lots analyzed for daily gain, some differences also existed in the amount of protein consumed per animal under various experiments. While attempts were made to include protein as a variable in the production functions, it was generally impossible because of the small number of observations and thus degrees of freedom.

Interpretation of results obtained with experimental animals fed in groups is often complicated by variations in performance of individual animals. The intake of insufficient essential nutrients, including vitamins and minerals, may result from a lack of appetite. Sickness and timidity may retard the growth rate of animals. Competition of animals may encourage the cattle to eat. There is a difference in capacity to consume and to utilize feed efficiently.[6]

Although there is considerable information available on the feed lot performances of steers fed rations containing different proportions of concentrates to roughages, there is little information on the effect of grain-roughage ratios on the digestibility of different nutrients.

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[6] D. Richardson, "Effects of Roughage-Concentrate Ratio in Cattle Fattening Rations on Gain, Feed Efficiency, Digestion and Carcass," Journal Animal Science, May 1961, 20:316-318.

Grain is not only a substitute for forage in producing meat, but also is generally a substitute for time. In order to attain the same degree of carcass quality, it is necessary that roughage fed animals be carried to a heavier weight than those fed grain in the wintering ration. Forage and time may be considered technical complements which together substitute for grain. A shorter time span is required for an animal fed a "high-grain" ration than one fed a "high-roughage" ration in ascertaining a given output of product of a specific grade.

The final solution of the problem may depend on establishing the nature and rate of substitution of various forages for time, labor, and other capital resources in addition to grain.[7] By recognizing all other independent variables and holding them constant for this study, it is assumed the influence of these other variables does not invalidate the results of this study.

REVIEW OF LITERATURE

It is interesting to note that in most feeding experiments, the cattle fed the ration containing the highest levels of concentrates did not in all cases produce the largest gains. Generally cattle fed rations containing two or three parts of concentrates to one of roughage have made the greatest gain.

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[7] Earl O. Heady, "Diversification in Resource Allocation and Minimization of Income Variability," Journal Farm Economics, Nov. 1952, 34:482-496.

Stanley (1953) group fed steers rations containing the following concentrate to hay ration: 2:1, 1:1, 1:2, and 1:3. Average daily gains made by the steers fed the four rations respectively were: 2.71, 2.66, 2.52, and 2.46 pounds.[8]

Dowe, _et_. _al_. (1950-1951) reported the result of two group feeding trials in which rations containing the following proportions of concentrates to alfalfa hay were fed: 1:1, 2:1, 3:1, 4:1, and 5:1. The steers fed the 3:1 ratio made the largest gain in the 1950 trial while in the 1951 trial, the steers fed the 2:1 ratio made the largest gains.[9]

Keith _et_. _al_. (1952) individually fed sixty steer calves and forty yearling steers rations containing the following concentrate to hay ratios: 1:2, 1:1, 2:1, 3:1, 4:1, and 1:3. The steer calves fed the ratio of concentrate to hay of 2:1 made the most rapid average daily gain of 2.01 pounds. The yearling steers fed the 3:1 ratio made the largest daily gain of 1.91 pounds.[10]

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[8] T. W. Dowe, "Effects of the Corn Alfalfa Hay Ratio on the Digestibility of the Different Nutrients by Cattle," _Journal Animal Science_, May 1955, 14:340.

[9] _Ibid_.

Cornell (1952, 1953, and 1954) presented the results of three group feeding trials in which fattening steers were fed rations containing different ratio's of concentrates to roughage. In the 1952 and 1954 trial the steers fed the 3:1 ratio made the most rapid gains while in the 1953 trial, the steers fed the 2:1 ratio made the largest gains.[11]

Richard, Smith, and Cox (1953) group fed steers on rations containing the following concentrate to hay ratio: 1:1, 3:1, and 5:1. These workers reported all lots made satisfactory gains, but the group fed 3:1 ratio of concentrates to roughages made the largest average daily gain.[12]

In summary, the previous studies regarding the amount of gain for wintering rations indicates that generally steers fed various quantities of grain concentrates make the greatest gain. Other factors of production not analyzed in this research influence the most efficient use of grain for maximum output. Because of these other factors of production, the greatest gain is not attained when steers are fed rations containing all grain or even very high levels of grain to roughage. Previous research reveal that there is a combination of grain and roughage amounts necessary to physically produce the maximum amount of beef from wintering rations.

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[10] Ibid., p. 341.

[11] Ibid.

[12] Ibid.

CHAPTER III

THE PRODUCTION FUNCTION

Production of beef can be represented as a functional relationship in the manner: $Y = \quad (H, G, X_1, X_2 \ldots X_n)$ where Y refers to the gain per beef animal, while H and G refer to amounts of hay and grain fed respectively. Other elements or resources, represented by the X's, also are necessary or can be used in beef production. These resources can be of any number and may refer to capital, protein, or any other variable in beef production.[13] Only hay equivalents and grain equivalents are considered as variables in this research. The remaining feeds or variables were considered (1) held constant, or (2) not present at all.

An illustration of a hypothetical production surface is shown in Figure 7, with a segment labeled, "wintering phase." The wintering phase applies to a narrow interval in the total growth range of beef steers. The span of weight is from 450 pounds to 700 pounds. It is expected that the surface will be slightly curvilinear in the wintering phase of growth.

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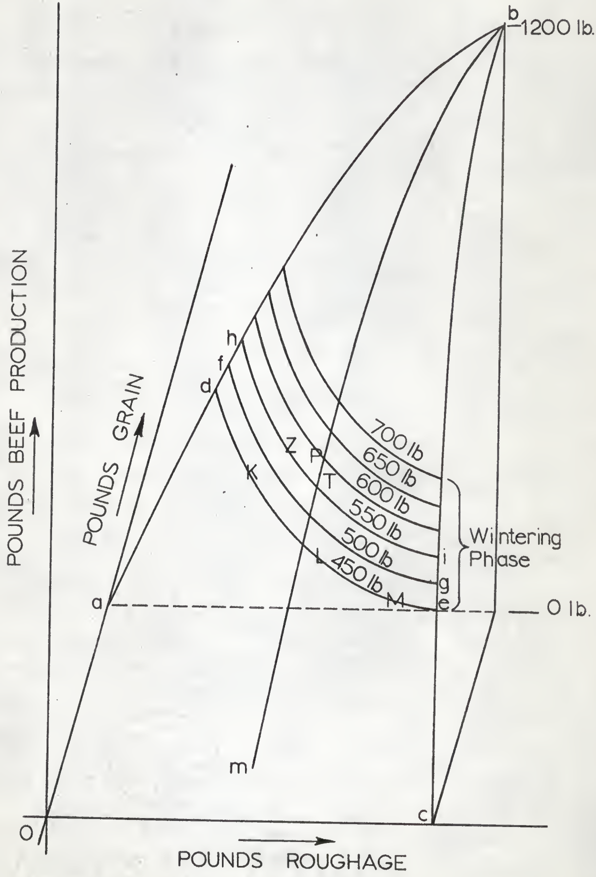
[13] Heady, *Economics of Agricultural Production and Resource Use*, p. 73.

FIG. 7
Hypothetical Production Surface



The rectangular axes indicate quantities of two feeds, roughage and grain in pounds while the vertical axis represents production weight per calf in pounds. Figure 7 provides a more likely hypotheses for cattle: The surface is curved in both vertical and horizontal directions. The vertical curvature, i.e. lines mb, ab, or cb which are concave or "curved downward rather than straight", indicates that for any particular combination of the two feeds, there is diminishing productivity of feed. The contour lines, fg, hi, and de, are iso-quants showing possible combinations of the two feeds which will produce a given level of beef output. Since they are curved, they indicate that many combinations of the two feeds can be used for any one gain, but increasing amounts of one are necessary to replace each pound of the other as proportions are changed.[14]

The design of many feed studies does not directly provide an estimate of a contour such as ab, or a portion of the production surface deih, however, when beef cattle are given additional grain and are allowed to select their own forage, two things tend to happen: (1) the animal eats more grain and less forage (a movement from right to left on the production surface) and (2) output increases (a movement upward between de, fg, and hi, because the beef animal's stomach is becoming less of a limiting factor). The concentrated grain contains a greater amount of feed nutrients and energy value than equivalent volume of hay.[15]

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[14] Earl O. Heady, _et al._ _New Procedures in Estimating Feed Substitution Rates and in Determining Economic Efficiency in Pork Production_, Iowa State Agricultural Experiment Station Research Bulletin 409, May 1954, p. 902.

Thus, the curve traced out may be neither a true substitution contour nor a true input-output relationship (relationship of pounds of gain to feed input as the latter is varied with feeds held in fixed proportions) but tends to confound the two.[16] There is further complication of the substitution contour and input-output relationship when meat animals are not carried to the same weight. This is illustrated by the following example.

Suppose three lots of cattle are started at the same weight, indicated by contour de, and are fed rations indicated by K, L, and M, in Figure 7. Now if the first lot is finished at a weight indicated by the level Z, the second at P, and the third at T, the two relationships are again concerned. Since ration T involves a heavier weight than P and Z, the differences in feed consumption are due to (1) the diminishing productivity of a single feed combination as it is transformed into a product as well as (2) the diminishing rate of substitution of one feed for another for a given level of output.[17]

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[15] Earl O. Heady and Russell O. Olson, Substitution Relationships, Resource Requirements and Income Variability in the Utilization of Forage Crops, Iowa State Agricultural Experiment Station Research Bulletin 390, Sept. 1952, p. 892.

[16] Ibid., p. 931.

Thus, the substitution is at a diminishing marginal rate in general; each added unit of roughage replaces a smaller quantity of grain than previously. The level or rate of substitution changes with each combination of the two production elements. The phenomen of decreasing marginal productivity of variable resources applied to single units of livestock is easily explained. For the meat producing animals such as beef, the output per animal can be increased only by carrying the animal to heavier and heavier weights.[18]

For the total gain per animal, and for daily gain, the product iso-quants may fall within a set of boundaries or a boundary may exist on one side. Physiological factors such meat grade, stomach capacity, minimum forage intake, maximum grain intake, help set these expansionary limitations. The boundaries are indicated geometrically when the respective iso-quants become asymptotic to the roughage or grain axes. Because of the complexity of the analysis herein and the array of data, only feed inputs have been included in estimates of the production function.[19]

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[17] Ibid.

[18] Heady, Economics of Agricultural Production and Resource Use, p. 73.

The feed production function for cattle includes mainly a short range of increasing marginal productivity and a wider range of decreasing marginal productivity.[20] Increasing marginal productivity of feeds exists either during the first part of the growing phase or when the ration is below the level required for maintenance. The marginal product shifts from an increasing to a decreasing nature before weaning. Therefore, previous gains must be maintained over a longer period of time as an added gain of fifty pounds is made late rather than early in the growing period.

While the factor-product relationship in livestock feeding is mainly one of decreasing marginal feed productivity, decreasing total and negative marginal returns prevail.[21]

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[19] T. W. Dowe, _op_. _cit_., p. 340.

[20] Heady, _Economics of Agricultural Production and Resource Use_, p. 72.

[21] _Ibid_., p. 73.

"Perhaps substitution rates are linear within some ranges of livestock."[22] Maximum feed intake and maximum output is possible only as grain is substituted for forage.

In summary, an understanding of the production function for wintering steers provides the setting for this research.

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[22] Earl O. Heady, "A Production Function and Marginal Rates of Substitution in the Utilization ofFeed Resources by Dairy Cows," Journal of Farm Economics, Nov. 1951, 33:486.

CHAPTER IV

RESULTS OF THE RESEARCH

The results of the research consist of (1) the derived physical relationships, and (2) the economic relationships of factors of production.

THE DERIVED PHYSICAL RELATIONSHIPS

The purposes of analyzing the feed input-output relationship was to estimate the actual regression plane including the relationships at various weight intervals. Graphic analysis of relationship at selected weight intervals (Figures 1 to 6) appeared to be inconclusive. The scattering of data was so diverse, a common trend line was not apparent for each weight interval. Through computer analysis, the regression plane or production surface was determined for average daily gain for the entire wintering period and for the entire winter weight gain.

From the experimental results for the initial thirty-nine lots of cattle, regression equations were derived to predict daily gain per head for vaying quantities of hay and grain equivalent. Three different regression equations were tested.[23]

$$(2) \quad Y = aH^{b1}\ G^{b2}$$

$$(3) \quad Y = a + b_1H + b_2G + b_3H^2 + b_4G^2 + b_5HG$$

$$(4) \quad Y = a + b_1H + b_2G + b_3 \quad G$$

In the above equations Y refers to gain per head per day, a is a constant value, H refers to roughage equivalent and G refers to grain equivalent. The b's are respective coefficients for the independent variables H and G.

A regression equation is desired which (1) allows the gain realized from one feed to depend on the quantity of the other, (2) allows diminishing productivity of one feed by itself or two feeds together, (3) allows diminishing rates of substitution, (4) allows the product contour lines to become asymptotic if a sufficient range of observations is available.

The logarithmic equation does not allow substitution rates to change along a scale or ration line, but allows the feeds to become limitational. It assumes constant elasticity of production, but possible diminishing marginal productivity. A one percent increase in the amount of one feed, the other constant, will result in the same percentage increase in output over all inputs.[24]

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[23] *Ibid.*, p. 490.

[24] *Ibid.*

The second production function is acceptable when considering elasticity of production and changeable substitution rates. It allows for a changing elasticity of production, as well as diminishing returns for inputs. Since the regression coefficients for the roughage (H) and grain (G) terms are positive and negative, the equation indicates possible increasing or decreasing returns in part of the range of observations. Thus logically the function may be acceptable in terms of previous findings of diminishings returns.[25]

In the third equation, the productivity of one feed does not depend on the amount of the other one which is fed.

Of the three regression equations used, computer information revealed the second equation to best fit the condition of this research. However, by utilizing daily gain information from Table 2, a statistically acceptable regression equation was determined for the entire wintering period.

With Y as daily gain and H and G as pounds hay and grain equivalent respectively, the following coefficients were developed for the production function:

$$(5)\quad Y = .706533 - .007513\ H + .495437\ G + .0019475\ H^2 - .01858\ G^2 - .0243568\ GH.$$

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[25] *Ibid.*

The statistical significance of the above coefficients for regression is shown in Appendix Table 3. A comparison of Y the estimated gain to the actual gain Y is shown in Table 2. The relationship of one pound daily gain to various hay and grain inputs is shown in Figure 8.

By using the production function $Y = .706533 - .007513\,H + .495437G + .001948\,H^2 - .024357\,HG$, where Y indicates gain per head per day, H indicates hay equivalent, and G indicates grain equivalent, the iso-product curve derived. The iso-product equation is given below (equation 6) for 1 pound gain per head per day.

$$(6) \quad G = \frac{.495437 - .024357\,H + \;\; .000736H^2 - .024692H + .223648}{.037160}$$

This relationship is expressed geometrically in Figure 8. Other iso-product curves for daily gain per head per day other than 1 pound could be determined but were not in this analysis. Actual gain per head per day varied from .36 pounds to 2.09 pounds.

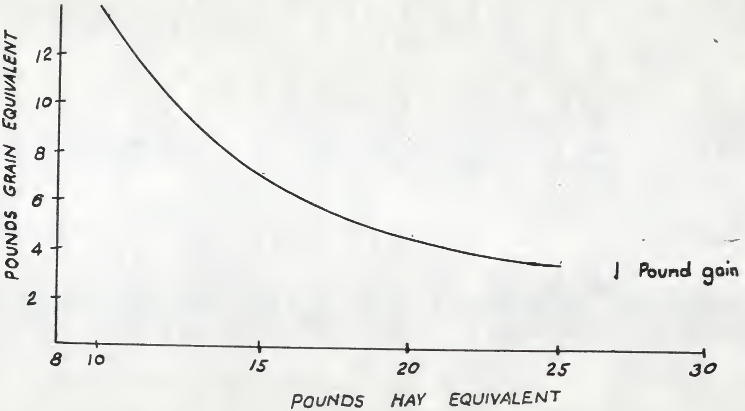

FIG. 8

Grain and Forage for One Pound Daily Gain per Head

MARGINAL RATE OF SUBSTITUTION

Marginal rates of substitution were derived from the first derivative (equation 7) of the iso-product equation and indicate the change in grain equivalent for each 1 pound change in hay equivalent. The equation for the marginal rates of substitution is as follows:

$$(7) \quad \frac{dG}{dH} = .655463 + \frac{.019806H - .332239}{.000736H^2 - .024692H + .223648}$$

Marginal rates of substitutions for four points are shown in Table 4. Figure 9 is a two dimensional diagram incorporating two feed price ratios typical of the ten years studied. Economic implications are discussed in a later section.

Table 4 indicates the hay equivalents and grain equivalents for various feed combinations and the substitution relationships in producing a 1 pound gain.

The various rations result in utilization of different quantities of roughage equivalent to grain equivalent. In Heady's study, the product contour equation was derived directly and shows the relationship of total forage consumption X_1 measured in terms of pounds of hay to total grain consumption X_2 per 100 pounds of beef.[27] Forage and grain forms

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[27] *Ibid*.

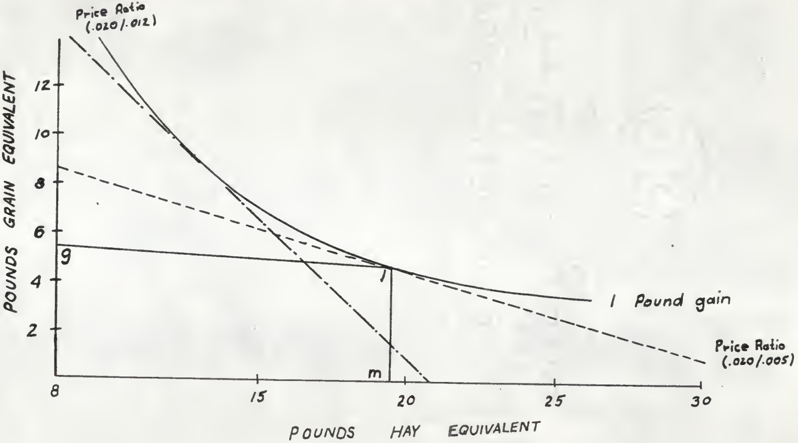

FIG. 9

Relationship of Prices to Iso-product Curve
for Selecting a Minimum Cost Ration

TABLE 4

RELATIONSHIP OF ONE POUND OF DAILY GAIN TO HAY AND GRAIN EQUIVALENTS

Feed Combinations to Produce 1 Pound gain per head per day		Marginal rate of substitution (pounds of grain replaced by 1 pound of hay) $\frac{dG}{dH}$	Pounds hay required to replace 1 pound of grain
Pounds of Hay	Pounds of Grain		
10	12.80	1.2545	.79
15	7.24	.8922	1.12
20	4.48	.2433	4.11
25	3.94	.0230	43.47

were similar in this study. As in the Heady study, all lots of cattle were purchased in the fall. In his experiment the cattle were wintered on the same growing ration until the beginning of the pasture season in May. Where his study derived the product contour for 100 pounds gain, this study was based on average daily gain per head.

The contour equation in the Iowa experiment is given below, where X_1 refers to hay and X_2 refers to grain required for 100 pounds of gain. The equation listed was selected in the sense of statistical probability over others.

$$X_2 = 111.15 - .4219X_1 + .0000686X_1^2$$

> "In production of 100 pounds of choice beef on yearling steers it was found that 1 pound of hay replaced .367 pounds of grain in a ration consisting of 400 pounds of hay and 953 pounds of grain. It replaced only .0102 pounds of grain in producing the same quantity of choice beef with a ration containing 3000 pounds of hay and 463 pounds of grain."[28]

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[28] *Ibid.*, p. 893.

TABLE 5

SUBSTITUTION RELATIONSHIPS IN THE PRODUCTION OF CHOICE BEEF[a]

Feed combinations for producing 100 pounds of beef		Marginal rate of substitution of hay for grain	Pounds of hay required to replace 1 pound of grain
Lbs. of Hay X_1	Lbs. of Grain X_2		
(1)	(2)	(3)	(4)
400	953.4	.3670	2.72
600	882.7	.3396	2.86
800	817.5	.3121	3.21
1,000	757.9	.2847	3.51
1,200	703.7	.2572	3.89
1,400	654.0	.2298	4.35
1,600	611.8	.2023	4.95
1,800	574.00	.1749	5.71
2,000	541.8	.1474	6.80
2,200	515.1	.1200	8.33
2,400	493.8	.0925	10.99
2,600	478.0	.0651	15.38

[a] *Ibid.*, p. 894.

The results of Heady's study plotted in Figure 10 compare with this research when we considered that in both cases we are dealing with an elasticity of production of less than 1.0. It was noted earlier in Figure 8 and Figure 9, the 1 pound iso-quant becomes nearly inelastic or nearly parallel to the horizontal axis. This can be explained by the fact that the experimental data contained few cases where any grain was fed to lighter weight steers and there were no cases analyzed where grain was fed without roughage. Since beef cattle are ruminants, it can be expected that the rate at which grain substitutes for roughage would be much less than for other livestock were the cattle ration to start from grain alone. Actual production is represented by systems varying all the way between a beef steer which utilizes forages alone to drylot feeding operations which include steers fed three times as much grain as forage.

DETERMINATION OF ECONOMIC RELATIONSHIPS

The data derived through the previously explained analysis of physical relationships are used with feed price relationships to specify least cost combinations. As with the information gained earlier from this research, it is necessary

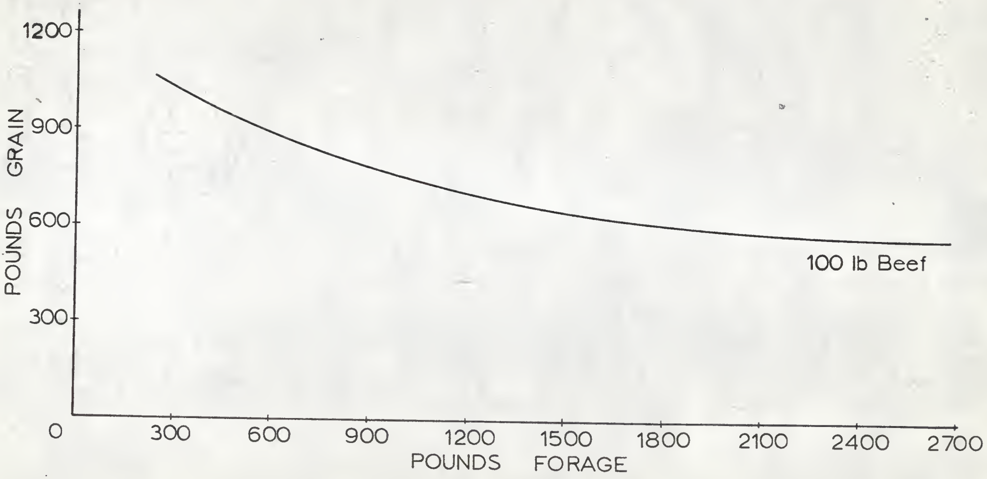

FIG. 10

Grain and Forage for One Hundred Pounds of Beef to determine whether the feeds do substitute for each other. Equally important it is necessary to determine the rates of substitution and whether rates are constant, increasing, or decreasing. As indicated earlier, the feeds substitute at a diminishing rate. The cattle producer desiring a least cost ration would equalize the marginal rate of feed substitution with the price ratios of the feeds. The optimum degree of efficiency is then dependent, to a large degree, on the technical relationships between input and outputs for each factor and any technical conditions of complementary or supplementary for factors when used in combinations.[29] Therefore, the producer is interested in two types of information (1) the feed substitution ratios and (2) feed price ratios.

Table 6 shows typical price ratios of feed during the period studied 1948-1958. Actual prices are indicated in Appendix Table 4 which are averaged in Appendix Table 5. Appendix Table 6 shows the actual price ratio, i.e. numbers 1 through 7 in Table 7, corresponding to the various lots of steers studied in this analysis.

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[29] Heady, *et al*, *op*. *cit*., p. 949.

TABLE 6

PRICE RATIOS DETERMINED IN DOLLARS PER POUND OF GRAIN/ROUGHAGE DURING TEN YEAR PERIOD.[a]

Ratio Number	Ratio
1	.020/.012
2	.021/.013
3	.022/.014
4	.023/.015
5	.024/.016
6	.025/.017
7	.020/.005

[a] United States Department of Agriculture, Agricultural Prices, (Washington: Government Printing Office), 1946-1958.

Based on the 1 pound iso-product curve derived in this study, and using the extreme range in price ratios (Table 6), substitution of grain for hay is economically and physically possible. Within the range of prices this would be a ration of 4 to 5 pounds of grain equivalent with about 19 pounds of roughage equivalent at one extreme, to a ration of 9 pounds of grain and 12 pounds of roughage at the other extreme

(Figure 9). The rations containing the largest proportion of grain to roughage appear to be appropriate to the heavier weight cattle, i.e. 700 pounds.

In the end, the producer must make two decisions in wintering steers: (1) the ration fed for any one level of production or output (the feed substitution problem) and (2) the amount of the best ration to feed the animal and the marketing weight or level of production to be attained.

In this study, substitution of grain for roughage is possible and the marginal rates of substitution are decreasing. The minimum cost combination will be at the tangency of the iso-cost line respective to the iso-product line or when the slopes of the two lines are equal and the substitution ratio equals the inverse price ratio.

The substitution ratios are compared to the price ratios in determining rations which give the lowest feed cost per pound. Feed cost of producing any gain or output per animal is at a minimum when the feed substitution rate is inversely equal to the feed price ratio. In the following equations the sign refers to "change in" and hence G refers to the change in the grain feeds and H refers to the change in roughage feeds. P_h refers to the price of hay and P_g to the price of grain.

$$1_a \quad H/\ \ G = P_g/P_h \qquad\qquad 1_b \quad (\ \ H)(P_h) = (\ \ G)(P_g)$$

$$2_a \quad H/\ \ G \quad P_g/P_h \qquad\qquad 2_b \quad (\ \ H)(P_h) \quad (\ \ G)(P_g)$$

$$3_a \quad H/\ \ G \quad P_g/P_h \qquad\qquad 3_b \quad (\ \ H)(P_h) \quad (\ \ G)(P_g)$$

In explaining the above equations, $H/\ \ G$ refers to the rate of substitution of grain for roughage (the amount of roughage replaced by each unit of grain). Equations 1_a and 1_b illustrate that when the rate of substitution of grain for hay is equal to the inverse price ratio, the value of grain needed to replace roughage is equal to the value of roughage replaced. Equations 2_a and 2_b indicate that when the substitution rate of grain equivalent for roughage equivalent is greater than the inverse price ratio of the grain to roughage, grain should be substituted for roughage. This equation more nearly illustrates the expected results of the research. The amount spent on grain is less than the value of hay replaced.[30]

For every change in the price ratio, a different combination of feeds will give the least cost combination, if substitution is at a diminishing rate.[31] If the reverse price relationship existed, it would appear to be more economical to feed higher levels of roughage. Factors that must not be overlooked in an interpretation of these results are the length of time necessary to produce the gain and the type of gain placed on them.

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[30] Heady, *et al*, *op*. *cit*., p. 910.

[31] Heady and Olson, *op*. *cit*., p. 928.

The path of the most profitable ration for increasing feed inputs and gain is called the expansion path. Since the relationship of feed inputs for gains other than 1 pound were not presented, the expansion path is mentioned only because of the similarity of the 1.0 pound iso-quant the results of the Iowa study. The results of this research indicate that physical and economic substitution of grain for hay does occur within the appropriate boundaries of the production surface and considering the range of prices occurring during the ten year period. In all cases presented, the producer is faced with a production function having an elasticity coefficienty less than 1.0.[32]

When comparing prices, it is assumed that all costs of grinding and feeding are the same for all feeds. Also some feeding operations require storage of grain for a relatively long time. Variations in storage are assumed equal.

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[32] Heady, _et_. _al_., _op_. _cit_., p. 936.

CHAPTER V

SUMMARY

In summary, this study has attempted to show the economic implications of roughage and grain substitution in beef cattle wintering rations. The statistical programming resulted in information from thirty-nine lots of cattle for a ten-year period, with a comparison of the variables roughage and grain to rate of daily gain per head. From these initial thirty-nine lots, information from twenty-one was used to plot the scattered production surface for graphic weight interval analysis. The graphic analysis of fifty pound weight intervals was inconclusive due to an apparent high degree of variation.

A mathematical regression equation was derived for daily gain per head. Within the logical boundaries of the production surface, the 1 pound iso-product curve falls within the realm of expectations and allowed minimum cost combinations to be determined.

Any such analysis is complicated by difficulties in keeping all other variables constant. However, all lots studied were "control" lots, i.e. received no experimental treatment. Experimental cattle are purchased with intentions of maintaining a high degree of uniformity and statistically there was no significant between-year variation. It is recognized that only a short span of growth is considered in this research in respect to the complete production span for cattle from birth to finished weights. The segment is concerned with weights from 450 pounds to 700 pounds and is restricted to wintering type of rations.

APPENDIX I

APPENDIX TABLE I - ACTUAL FEED UTILIZED FOR WINTERING CALVES

December 5, 1946 to April 24, 1947
140 Days

Date Interval	Corn	Milo	Oats Straw	Sorg. Silage	Alfalfa	Pr. Hay	CSM	SBM	Total Average Weight	Gain Per Head
AEc. (1) AH. (1)										
Initial Weight									410.7	
Dec. 5 (28) Jan. 2				692			28		454.5	45.4
Jan. 2 (28) Jan. 30				733			28		490.0	35.5
Jan. 30 (29) Feb. 27				742			28		508.0	18.0
Feb. 27 (29) Mar. 27				807			28		530.5	23.5
Mar. 27 (28) Apr. 24				870			28		545.5	15.0
AEc. (2) AH. (2)										
Initial Weight									410.5	
Dec. 5 (28) Jan. 2			211.5				28		433.0	22.5
Jan. 2 (28) Jan. 30			269.2				28		443.5	10.5
Jan. 30 (27) Feb. 27			254.5				28		453.5	10.0
Feb. 27 (28) Mar. 27			278.1				28		455.0	01.5
Mar. 27 (28) Apr. 24			271.2				28		461.0	.6
AEc. (3) AH. (3)										
Initial Weight									411.2	
Dec. 5 (28) Jan. 2			149.1		114.0				450.5	39.3
Jan. 2 (28) Jan. 30			206.1		112.0				448.5	-02.0
Jan. 30 (27) Feb. 27			200.0		112.0				459.5	11.0
Feb. 27 (28) Mar. 27			234.5		112.0				472.5	13.0
Mar. 27 (28) Apr. 24			234.2		112.0				466.0	-06.5

APPENDIX TABLE 1 - ACTUAL FEED UTILIZED FOR WINTERING CALVES - CONTINUED
December 5, 1946 to April 24, 1947
140 Days

Date Interval	Corn	Milo	Oats Straw	Sorg. Silage	Alfalfa Hay	Pr. Hay	CSM	SBM	Total Average Weight	Gain Per Head
AEc. (4) AH. (4)										
Initial Weight									410.0	
Dec. 5 (28) Jan. 2			104.6	346.0			28		456.5	46.5
Jan. 2 (28) Jan. 30			121.6	370.0			28		465.5	09.0
Jan. 30 (27) Feb. 27			110.3	371.0			28		480.5	15.0
Feb. 27 (28) Mar. 27			403.5	157.9			28		496.0	15.5
Mar. 27 (28) Apr. 24			435.0	178.5			28		516.0	20.0
AEc. (5) AH. (5)										
Initial Weight									411.5	
Dec. 5 (28) Jan. 2			45.2	346.0	106.0				458.5	47.0
Jan. 2 (28) Jan. 30			46.4	370.0	112.0				460.0	01.5
Jan. 30 (27) Feb. 27			41.3	371.0	112.0				470.5	10.5
Feb. 27 (28) Mar. 27			73.6	403.5	108.0				480.0	09.5
Mar. 27 (28) Apr. 24			100.9	435.0	112.0				509.5	29.5

APPENDIX TABLE 1 - ACTUAL FEED UTILIZED FOR WINTERING CALVES - CONTINUED

November 25, 1949 to April 15, 1950
141 Days

Date Interval	Ground Shelled Corn	Milo	Oats	Sorg. Silage	Alfalfa	Pr. Hay	CSM	SB Pellets	Total Average Weight	Gain Per Head
(Nine Head)										
AEc. (11) AH. (2)										
Initial Weight									430.0	
Nov. 25 (28) Dec. 23				744.4				31.1	461.0	31.0
Dec. 23 (28) Jan. 20				722.2				31.1	489.0	28.0
Jan. 20 (28) Feb. 17				933.3				31.1	521.0	32.0
Feb. 17 (28) Mar. 17				988.9				31.1	557.0	26.0
Mar. 17 (28) Apr. 15				1033.3				32.2	590.0	33.0
(Nine Head)										
AEc. (12) AH. (3)										
Initial Weight									434.0	
Nov. 25 (28) Dec. 23						321.7		31.1	462.0	28.0
Dec. 23 (28) Jan. 20						399.4		31.1	504.0	42.0
Jan. 20 (28) Feb. 17						384.3		31.1	531.0	27.0
Feb. 17 (28) Mar. 17						392.4		28.0	557.0	26.0
Mar. 17 (28) Apr. 15						338.9		29.0	591.0	34.0
(Ten Head)										
AEc. (13) AH. (4)										
Initial Weight									432.0	
Nov. 25 (28) Dec. 23	56.0					261.2		28	461.0	29.0
Dec. 23 (28) Jan. 20	56.0					327.5		28	503.0	42.0
Jan. 20 (28) Feb. 17	56.0					300.0		28	543.0	40.0
Feb. 17 (28) Mar. 17	56.0					335.4		28	572.0	29.0
Mar. 17 (28) Apr. 15	56.0					304.6		29	618.0	46.0

APPENDIX TABLE 1 - ACTUAL FEED UTILIZED FOR WINTERING CALVES - CONTINUED
November 25, 1949 to April 15, 1950
141 Days

Date Interval	Ground Shelled Corn	Milo	Oats	Sorg. Silage	Alfalfa	Pr. Hay	CSM	SB Pellets	Total Average Weight	Gain Per Head
(Ten Head)										
AEc. (14) AH. (5)										
Initial Weight									432.0	
Nov. 25 (28) Dec. 23	107.0					206.1		28	469.0	37.0
Dec. 23 (28) Jan. 20	112.0					290.0		28	527.0	58.0
Jan. 20 (28) Feb. 17	112.0					279.0		28	569.0	42.0
Feb. 17 (28) Mar. 17	117.0					294.4		28	617.0	48.0
Mar. 17 (28) Apr. 15	116.0					316.6		29	652.0	35.0

APPENDIX TABLE 1 - ACTUAL FEED UTILIZED FOR WINTERING CALVES - CONTINUED
December 22, 1951 to May 2, 1952
132 Days

Date Interval	Corn	Milo, Ground	Oats	Sorg. Silage	Alfalfa	Pr. Hay	CSM	SB Pellets	Total Average Weight	Gain Per Head
(Ten Head)										
AEc. (50) AH. (2)										
Initial Weight									389.0	
Dec. 22 (27) Jan. 18				595.0			27.0		412.0	23.0
Jan. 18 (28) Feb. 15				580.5			28.0		427.0	15.0
Feb. 15 (28) Mar. 15				575.0			29.0		446.0	19.0
Mar. 15 (21) Apr. 5				420.0			21.0		463.0	17.0
Apr. 5 (27) May 2				580.0			27.0		476.0	13.0
(Ten Head)										
AEc. (51) AH. (3)										
Initial Weight									389.0	
Dec. 22 (27) Jan. 18						278.6	27.0		419.0	30.0
Jan. 18 (28) Feb. 15						298.7	28.0		443.0	24.0
Feb. 15 (28) Mar. 15						343.1	29.0		482.0	39.0
Mar. 15 (21) Apr. 5						211.5	21.0		484.0	02.0
Apr. 5 (27) May 2						365.3	27.0		516.0	32.0
(Ten Head)										
AEc. (52) AH. (4)										
Initial Weight									390.0	
Dec. 22 (27) Jan. 18		54.0				258.5	27.0		428.0	38.0
Jan. 18 (28) Feb. 15		56.0				274.6	28.0		459.0	31.0
Feb. 15 (28) Mar. 15		58.0				325.0	29.0		499.0	40.0
Mar. 15 (21) Apr. 5		42.0				216.5	21.0		527.0	28.0
Apr. 5 (27) May 2		54.0				350.9	27.0		551.0	24.0

APPENDIX TABLE 1 - ACTUAL FEED UTILIZED FOR WINTERING CALVES - CONTINUED
December 22, 1951 to May 2, 1952
132 Days

Date Interval	Corn	Ground Milo	Oats	Sorg. Silage	Alfalfa	Pr. Hay	CSM	SB Pellets	Total Average Weight	Gain Per Head
(Ten Head)										
AEc. (53) AH. (5)										
Initial Weight									391.0	
Dec. 22 (27) Jan. 18		110.0				291.2	27.0		440.0	49.0
Jan. 18 (28) Feb. 15		112.0				262.4	28.0		474.0	34.0
Feb. 15 (28) Mar. 15		116.0				325.5	29.0		518.0	44.0
Mar. 15 (21) Apr. 5		84.0				213.0	21.0		547.0	29.0
Apr. 5 (27) May 2		106.0				348.6	26.5		572.0	25.0

APPENDIX TABLE 1 - ACTUAL FEED UTILIZED FOR WINTERING CALVES - CONTINUED

December 19, 1952 to May 4, 1953

136 Days

Date Interval	Corn	Milo	Oats	Sorg. Silage	Alfalfa	Pr. Hay	CSM	SB Pellets	Total Average Weight	Gain Per Head
(Ten Head)										
AEc. (60) AH. (1)										
Initial Weight									360.0	
Dec. 19 (28) Jan. 16	121.0			495.0		82.0		28.0	433.0	73.0
Jan. 16 (28) Feb. 13	168.0			585.0		07.5		28.0	490.0	57.0
Feb. 13 (28) Mar. 13	141.0			560.0		59.5		28.0	538.0	48.0
Mar. 13 (27) Apr. 9	135.0			540.0		59.5		27.0	598.0	60.0
Apr. 9 (25) May 4	125			480.0		38.0		25.0	639.0	41.0
(Self-fed grain on pasture)										
(Ten Head)										
AEc. (62) AH. (3)										
Initial Weight									357.0	
Dec. 19 (28) Jan. 16	121.0			475.0		78.5		28.0	428.0	71.0
Jan. 16 (28) Feb. 13	168.0			555.0		----		28.0	480.0	52.0
Feb. 13 (28) Mar. 13	141.0			560.0		110.5		28.0	546.0	66.0
Mar. 13 (27) Apr. 9	135.0			535.0		55.5		27.0	594.0	48.0
Apr. 9 (25) May 4	125			480.0		59.5		25.0	641.0	47.0
(Self-fed grain in drylot)										
(Ten Head)										
AEc. (62A) AH. ( )										
Initial Weight									417.0	
Dec. 18 (28) Jan. 16						342.5		29.0	467.0	50.0

APPENDIX TABLE 1 - ACTUAL FEED UTILIZED FOR WINTERING CALVES - CONTINUED
December 19, 1952 to May 4, 1953
136 Days

Date Interval	Corn	Milo	Oats	Sorg. Silage	Alfalfa	Pr. Hay	CSM	SB Pellets	Total Average Weight	Gain Per Head
Jan. 1 (28) Feb. 13						328.0		28.0	501.0	34.0
Feb. 13 (28) Mar. 13						329.0		28.0	528.0	27.0
Mar. 13 (27) Apr. 9						365.5		27.0	548.0	20.0
Apr. 9 (25) May 4	(Fed only for Apr. 9 to Apr. 23)					218.0		14	550.0	02.0
(Self-fed grain in drylot)										

APPENDIX TABLE 1 - ACTUAL FEED UTILIZED FOR WINTERING CALVES - CONTINUED
November 30, 1955 to April 7, 1956
129 Days

Date Interval	Corn	Milo	Oats	Sorg. Silage	Alfalfa	Pr. Hay	CSM	SBM	Total Average Weight	Gain Per Head
(Nine Head)										
AEc. (81) AH. (18A)										
Initial Weight									391.0	
Nov. 30 (28) Dec. 28		100.0		711.0				28.0	434.0	43.0
Dec. 28 (29) Jan. 25		112.0		822.0				28.0	478.0	44.0
Jan. 25 (28) Feb. 22		112.0		893.0				28.0	546.0	68.0
Feb. 22 (28) Mar. 21		112.0		894.0				28.0	574.0	28.0
Mar. 21 (17) Apr. 7		68.0		509.0				17.0	602.0	28.0
(Nine Head)										
AEc. (81) AH. (18B)										
Initial Weight									391.0	
Nov. 30 (28) Dec. 28		100.0		711.0				28.0	443.0	52.0
Dec. 28 (29) Jan. 25		112.0		822.0				28.0	497.0	54.0
Jan. 25 (28) Feb. 22		112.0		893.0				28.0	573.0	76.0
Feb. 22 (28) Mar. 21		112.0		894.0				28.0	618.0	45.0
Mar. 21 (17) Apr. 7		68.0		509.0				17.0	642.0	24.0

[a] Lots 18A and 18B were combined making a total of 18 head for the winter program.

APPENDIX TABLE 1 - ACTUAL FEED UTILIZED FOR WINTERING CALVES - CONCLUDED
IMPLANTS FOR STEER CALVES ON A WINTERING RATION
December 5, 1957 to March 26, 1958

Date Interval	Corn	Milo	Oats	Sorg. Silage	Alfalfa	Pr. Hay	CSM	SBM	Total Average Weight	Gain Per Head
(Twenty Head)										
AEc. (103 AH. (22)										
Initial Weight									548.0	
Dec. 5 (28) Jan. 2		104.0		290.0		147.0		21.0	587.0	39.0
Jan. 2 (28) Jan. 30		112.0		420.0		203.5		28.0	642.0	55.0
Jan. 30 (28) Feb. 28		116.0		435.0		205.3		29.0	662.5	20.5
Feb. 28 (27) Mar. 25		100.0		375.0		200.0		25.0	708.5	46.0
(Ten Head)										
AEc. (104) AH. (1)										
Initial Weight									444.0	
Dec. 4[a] (26*) Jan. 2		88.7		600.0				26.0	479.5	35.5
Jan. 3 (30) Feb. 1		150.0		826.7				30.0	536.0	56.5
Feb. 2 (25) Feb. 26		125.0		656.7				25.0	587.5	51.5
Feb. 27 (28) Mar. 26		140.0		786.7				28.0	626.0	39.0
Mar. 27[b] (28**) Apr. 23		135.0		800.0				27.0	672.0	46.0
Apr. 24 (27) May 21		141.7		503.3	86.7			23.3	726.5	54.5
(Fifteen Head)										
AEc. (90) AH. (1)										
Initial Weight									446.0	
Dec. 4[a] (26*) Jan. 2		88.7		600.0				26.0	482.7	36.7
Jan. 3 (30) Feb. 1		150.0		826.7				30.0	538.7	56.0

APPENDIX TABLE 1 - ACTUAL FEED UTILIZED FOR WINTERING CALVES - CONCLUDED
IMPLANTS FOR STEER CALVES ON A WINTERING RATION
December 5, 1957 to March 26, 1958

Date Interval	Corn	Milo	Oats	Sorg. Silage	Alfalfa	Pr. Hay	CSM	SBM	Total Average Weight	Gain Per Head
Feb. 2 (25) Feb. 26		125.0		656.7				25.0	589.3	50.6
Feb. 27 (28) Mar. 26		140.0		786.7				28.0	621.3	32.0

[a] Feeding records did not start until December 8

[b] No silage Mar. 28; no feed records Mar. 29.

APPENDIX TABLE 2
HAY AND GRAIN EQUIVALENTS UTILIZED IN TWENTY ONE LOTS IN RELATION TO FIFTY POUND WEIGHT INTERVALS

Lot No.	Weight Interval of Feeder Steer (Pounds)	Total Feed Consumption		Feed Consumption /lb. Gain	
		Hay Equivalent (Pounds)	Grain Equivalent (Pounds)	Hay Equivalent (Pounds)	Grain Equivalent (Pounds)
1	400-450	228.5	0	4.57	0
	450-500	404.0	0	8.08	0
	500-550	653.5	0	13.07	0
2	400-450	252.5	0	5.05	0
	450-500	109.5	0	21.90	0
3	400-450	581.2	0	1.60	0
	450-500	402.0	0	17.50	0
4	400-450	224.0	0	4.48	0
	450-500	1145.0	0	22.90	0
	500-550	1221.5	0	24.43	0
5	400-450	260.5	0	5.21	0
	450-500	1090.0	0	21.80	0
11	400-450	360.0	0	7.20	0
	450-500	390.0	0	7.80	0
	500-550	424.0	0	8.48	0
	550-600	470.0	0	9.40	0
12	400-450	574.0	0	11.48	0
	450-500	475.0	0	9.50	0
	500-550	732.0	0	14.65	0
	550-600	499.5	0	9.99	0
13	400-450	450.5	96.5	9.01	1.93
	450-500	388.5	66.5	7.77	1.33
	500-550	375.0	70.0	7.50	1.40
	550-600	426.5	75.0	8.53	1.50

APPENDIX TABLE 2 - CONTINUED
HAY AND GRAIN EQUIVALENTS UTILIZED IN TWENTY ONE LOTS IN RELATION TO FIFTY POUND WEIGHT INTERVALS

Lot No.	Weight Interval of Feeder Steer (Pounds)	Total Feed Consumption		Feed Consumption /lb. Gain	
		Hay Equivalent (Pounds)	Grain Equivalent (Pounds)	Hay Equivalent (Pounds)	Grain Equivalent (Pounds)
14	400-450	278.5	145.0	5.57	2.90
	450-500	250.0	96.5	5.00	1.93
	500-550	332.0	133.5	6.64	2.67
	550-600	306.5	122.0	6.13	2.44
	600-650	452.5	157.0	9.05	3.14
50	400-450	463.3	0	9.26	0
	450-500	624.0	0	12.48	0
52	400-450	401.0	75.7	8.02	1.51
	450-500	406.5	69.0	8.13	1.38
	500-550	536.0	87.7	10.72	1.75
53	400-450	297.0	106.5	5.94	2.13
	450-500	377.0	139.0	7.54	2.78
	500-550	367.5	137.5	7.35	2.75
	550-600	696.0	201.5	13.92	4.03
60	400-450	158.0	83.0	3.16	1.66
	450-500	160.5	147.5	3.21	2.95
	500-550	237.0	147.0	4.74	2.94
	550-600	184.5	112.5	3.69	2.25
	600-650	222.0	152.5	4.44	3.05
62	400-450	155.5	85.0	3.11	1.70
	450-500	160.0	161.5	3.20	3.23
	500-550	211.0	107.0	4.22	2.14
	550-600	225.0	130.0	4.50	2.60
	600-650	338.0	133.0	6.76	2.66

APPENDIX TABLE 2 - CONCLUDED
HAY AND GRAIN EQUIVALENTS UTILIZED IN TWENTY ONE LOTS IN RELATION TO FIFTY POUND WEIGHT INTERVALS

Lot No.	Weight Interval of Feeder Steer (Pounds)	Total Feed Consumption		Feed Consumption /lb. Gain	
		Hay Equivalent (Pounds)	Grain Equivalent (Pounds)	Hay Equivalent (Pounds)	Grain Equivalent (Pounds)
62A	400-450	342.5	0	6.85	0
	450-500	482.5	0	9.65	0
	500-550	966.5	0	19.33	0
81	400-450	248.0	110.5	4.96	2.30
	450-500	280.0	121.0	5.60	2.42
	500-550	197.0	78.5	3.94	1.57
	550-600	376.0	152.5	7.52	3.05
103	550-600	300.0	127.0	6.00	2.54
	600-650	300.0	97.0	6.00	1.94
	650-700	487.5	71.5	9.75	1.43
104	450-500	253.5	119.0	5.07	2.38
	500-550	219.5	126.0	4.39	2.52
	550-600	191.5	115.0	3.83	2.30
	600-650	277.5	152.0	5.55	3.04
	650-700	218.0	123.5	4.36	2.47
90	450-500	245.5	115.0	4.91	2.31
	500-550	221.5	127.5	4.93	2.55
	550-600	194.5	117.5	3.89	2.35
	600-650	369.0	192.0	7.38	3.84

APPENDIX TABLE 3

STATISTICAL COEFFICIENTS FOR THE THREE EQUATIONS USED

1. $Y = a\ H^{b1}\ G^{b2}$

$a = 2.1013$

$b_1 = -.1452434$

$b_2 = .05381521$

2. $Y = a + b_1H + b_2G + b_3H^2 + b_4G^2 + b_5HG$ (39 observations)

$a = .706533$

$b_1 = -.007513$

$b_2 = .495437$

$b_3 = .00194752$

$b_4 = -.018580$

$b_5 = -.0243568$

$F(5,33) = 38.178395$

$t_1^2 = .0008541722$

$t_2^2 = 4.8499217$

$t_3^2 = .023751207$

$t_4^2 = .340852031$

$t_5^2 = 2.3152031$

$R^2 = .85260716$

$s_y^2 = .039944787$

$s_{b_1}^2 = .066081719$

$s_{b_2}^2 = .050610676$

$s_{b_3}^2 = .00015969015$

$s_{b_4}^2 = .00064767$

$s_{b_5}^2 = .0002562426$

3. $Y = a + b_1H + b_2G + b_3\ G$

$a = .69349890$

$b_1 = .01485515$

$b_2 = .30355790$

$b_3 = .17508960$

APPENDIX TABLE 4

ACTUAL PRICES FOR FEEDS AND BEEF

		1946				1947			Average
		NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	seven months
CORN	$/bu.	1.28	1.24	1.24	1.24	1.60	1.63	1.59	1.40
GRAIN SORGHUM	$/cwt.	2.27	1.97	2.03	2.15	2.57	2.70	2.72	2.34
BARLEY	$/bu.	1.24	1.20	1.20	1.16	1.27	1.29	1.28	1.23
OATS	$/bu.	.81	.81	.81	.82	.91	.87	.88	.84
WHEAT	$/bu.	1.89	1.91	1.89	2.02	2.54	2.45	2.48	2.17
BRAN	$/cwt.	3.20	2.89	2.61	2.54	3.07	3.15	3.16	2.95
SOYBEAN MEAL	$/cwt.	5.26	4.94	4.67	4.27	4.47	4.54	4.20	4.62
COTTON SEED MEAL	$/cwt.	5.25	5.11	4.84	4.33	4.48	4.52	4.31	4.69
LINSEED MEAL	$/cwt.	5.34	5.21	5.01	4.89	4.93	4.98	4.77	5.02
ALFALFA HAY	$/ton	21.50	21.50	22.00	20.00	20.00	21.50	21.00	21.07
PRAIRIE HAY	$/ton	13.00	14.50	14.50	14.00	14.50	15.50	15.50	14.50
STEERS									
CHOICE & PRIME		32.43	32.96	28.50	26.22	26.86	25.59	25.67	
GOOD		26.19	25.95	23.90	23.93	24.33	23.18	24.14	
STOCKER									
HEIFERS (average of 25.75 good & choice)		25.75	24.10	22.88	22.34	23.55	22.25	23.48	
STEERS		16.75	16.76	17.15	18.76	19.70	18.69	21.37	18.45

APPENDIX TABLE 4 - CONTINUED

ACTUAL PRICES FOR FEEDS AND BEEF

		1947 NOV.	DEC.	JAN.	FEB.	1948 MAR.	APR.	MAY	Average seven months
CORN	$/bu.	2.25	2.52	2.60	1.92	2.17	2.22	2.19	2.27
GRAIN SORGHUM	$/cwt.	3.29	3.61	3.77	2.77	3.36	3.56	3.58	3.42
BARLEY	$/bu.	1.65	1.81	1.92	1.52	1.72	1.75	1.65	1.72
OATS	$/bu.	1.10	1.18	1.28	1.02	1.17	1.20	1.13	1.15
WHEAT	$/bu.	2.74	2.77	2.80	2.06	2.14	2.21	2.14	2.41
BRAN	$/cwt.	3.77	3.93	4.29	4.01	3.90	4.21	4.27	4.05
SOYBEAN MEAL	$/cwt.	5.22	5.44	5.82	5.24	5.90	5.02	5.03	5.27
COTTON SEED MEAL	$/cwt.	5.07	5.28	5.46	5.26	5.13	5.07	5.03	5.19
LINSEED MEAL	$/cwt.	5.16	5.29	5.70	5.60	5.26	4.93	4.86	5.26
ALFALFA HAY	$/ton	22.50	24.00	23.00	20.00	19.00	19.00	22.00	21.36
PRAIRIE HAY	$/ton	14.00	19.00	14.00	11.00	15.50	o.50	13.00	13.71
STEERS									
CHOICE & PRIME		34.03	35.28	36.61	30.27	29.92	30.37	31.77	
GOOD		29.40	28.85	30.41	26.41	27.61	28.38	30.29	
STOCKER									
HEIFERS (average of good & choice)		28.44	29.70	30.50	26.08	27.31	28.40	29.82	
STEERS		20.99	21.26	24.99	23.72	23.78	26.39	26.40	23.32

APPENDIX TABLE 4 - CONTINUED

ACTUAL PRICES FOR FEEDS AND BEEF

		1948				1949			Average
		NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	seven months
CORN	$/bu.	1.21	1.25	1.28	1.15	1.23	1.26	1.22	1.23
GRAIN SORGHUM	$/cwt.	1.95	2.00	2.05	1.93	2.03	2.03	1.96	1.99
BARLEY	$/bu.	1.12	1.15	1.12	1.01	1.01	.99	.91	1.04
OATS	$/bu.	.78	.81	.81	.75	.76	.75	.70	.77
WHEAT	$/bu.	2.00	2.02	1.99	1.92	1.95	1.99	1.98	1.98
BRAN	$/cwt.	3.06	3.18	3.18	3.02	3.15	3.51	3.42	3.22
SOYBEAN MEAL	$/cwt.	4.38	4.64	4.48	4.14	4.09	4.15	4.17	4.29
COTTON SEED MEAL	$/cwt.	4.17	4.36	4.24	3.98	3.89	3.79	3.76	4.03
LINSEED MEAL	$/cwt.	4.41	4.71	4.82	4.61	4.40	4.29	4.22	4.50
ALFALFA HAY	$/ton	20.50	21.00	21.00	20.50	20.50	20.00	17.50	20.14
PRAIRIE HAY	$/ton	12.00	12.50	12.50	13.00	12.50	12.50	12.00	12.43
STEERS									
CHOICE & PRIME		36.67	35.28	30.52	25.72	25.64	25.84	25.82	
GOOD		31.53	28.85	30.41	23.35	24.80	24.46	24.80	
STOCKER									
HEIFERS (average of good & choice)		31.62	27.98	26.38	23.87	25.15	25.35	25.68	
STEERS		25.77	22.80	23.14	19.94	23.98	24.39	24.16	23.45

APPENDIX TABLE 4 - CONTINUED

ACTUAL PRICES FOR FEEDS AND BEEF

		1949				1950			Average
		NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	seven months
CORN	$/bu.	1.00	1.08	1.13	1.14	1.18	1.28	1.37	1.17
GRAIN SORGHUM	$/cwt.	1.43	1.66	1.77	1.77	1.82	1.92	2.05	1.77
BARLEY	$/bu.	.93	.96	.96	.95	.96	.99	1.05	.97
OATS	$/bu.	.71	.75	.78	.78	.79	.80	.83	.78
WHEAT	$/bu.	1.90	1.94	1.91	1.93	1.99	2.02	2.04	1.96
BRAN	$/cwt.	2.80	2.92	2.40	2.30	2.40	2.55	3.25	2.66
SOYBEAN MEAL	$/cwt.	4.36	4.32	4.10	3.95	4.05	4.10	4.45	4.19
COTTON SEED MEAL	$/cwt.	3.80	3.85	3.90	3.80	3.85	3.85	3.95	3.86
LINSEED MEAL	$/cwt.	4.20	4.36	4.55	4.40	4.40	4.50	4.65	4.44
ALFALFA HAY	$/ton	19.50	19.50	19.00	17.50	17.50	17.50	18.00	18.36
PRAIRIE HAY	$/ton	11.50	12.00	11.50	11.00	10.50	10.70	11.50	11.24
STEERS									
CHOICE & PRIME		35.83	37.66	36.60	35.03	31.89	30.20	31.02	
GOOD		29.00	30.05	28.11	27.18	27.31	27.18	29.20	
STOCKER									
HEIFERS (average of good & choice)		28.80	28.68	28.65	28.06	27.62	27.66	29.18	
STEERS		21.90	21.56	21.80	22.70	23.80	24.50	28.10	23.39

APPENDIX TABLE 4 - CONTINUED

ACTUAL PRICES FOR FEEDS AND BEEF

		1950		1951					
		NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	Average seven months
CORN	$/bu.	1.29	1.39	1.49	1.53	1.52	1.53	1.57	1.47
GRAIN SORGHUM	$/cwt.	1.65	1.85	2.10	2.25	2.16	2.15	2.20	2.05
BARLEY	$/bu.	1.11	1.20	1.23	1.31	1.28	1.28	1.29	1.24
OATS	$/bu.	.82	.90	.94	.97	.96	.97	.96	.93
WHEAT	$/bu.	1.98	2.08	2.14	2.26	2.15	2.20	2.14	2.14
BRAN	$/cwt.	2.55	2.60	2.80	2.80	2.85	3.10	3.20	2.84
SOYBEAN MEAL	$/cwt.	4.20	4.30	4.50	4.55	4.70	4.65	4.70	4.51
COTTONSEED MEAL	$/cwt.	4.45	4.65	4.85	4.90	5.00	5.00	5.10	4.85
LINSEED MEAL	$/cwt.	4.50	4.60	4.65	4.65	4.70	4.70	4.70	4.64
ALFALFA HAY	$/ton	20.00	20.50	21.50	22.50	22.50	24.00	23.30	22.04
PRAIRIE HAY	$/ton	12.00	12.50	13.00	13.50	13.00	13.50	14.00	15.00
STEERS									
PRIME & CHOICE		32.80	36.12						
GOOD		30.98	32.89	30.50	32.60	32.80	34.70	31.30	31.10
STOCKER									
HEIFERS (average of good & choice)		32.08	33.82						
STEERS		27.70	28.20						

APPENDIX TABLE 4 - CONTINUED

ACTUAL PRICES FOR FEEDS AND BEEF

		1951		1952					
		NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	Average seven months
CORN	$/bu.	1.67	1.80	1.77	1.69	1.69	1.74	1.73	1.73
GRAIN SORGHUM	$/cwt.	2.30	2.48	2.46	2.42	2.44	2.46	2.51	2.44
BARLEY	$/bu.	1.28	1.33	1.36	1.34	1.34	1.32	1.28	1.32
OATS	$/bu.	1.02	1.07	1.07	1.03	1.00	1.00	.95	1.02
WHEAT	$/bu.	2.25	2.26	2.25	2.23	2.24	2.23	2.14	2.23
BRAN	$/cwt.	3.40	3.60	3.55	3.50	3.55	3.60	3.50	3.53
SOYBEAN MEAL	$/cwt.	5.10	5.10	5.20	5.30	5.30	5.30	5.50	5.26
COTTONSEED MEAL	$/cwt.	5.10	5.10	5.20	5.40	5.30	5.30	5.40	5.26
LINSEED MEAL	$/cwt.	4.90	5.00	5.00	5.20	5.20	5.20	5.30	5.11
ALFALFA HAY	$/ton	28.50	31.00	32.00	29.50	28.00	28.00	25.50	28.93
PRAIRIE HAY	$/ton	19.00	21.00	21.50	21.00	19.50	19.50	19.00	20.07
STOCKER & FEEDER CATTLE		31.20	31.80	29.70	30.40	30.10	30.30	30.50	30.57

APPENDIX TABLE 4 - CONTINUED

ACTUAL PRICES FOR FEEDS AND BEEF

		1952		1953					
		NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	Average seven months
CORN	$/bu.	1.51	1.55	1.53	1.44	1.48	1.45	1.51	1.50
GRAIN SORGHUM	$/cwt.	2.70	2.70	2.68	2.49	2.50	2.35	2.36	2.54
BARLEY	$/bu.	1.34	1.38	1.39	1.29	1.35	1.31	1.31	1.34
OATS	$/bu.	.95	.96	.94	.87	.88	.85	.84	.90
WHEAT	$/bu.	2.18	2.16	2.13	2.06	2.12	2.10	2.06	2.12
BRAN	$/cwt.	3.25	3.25	3.20	3.00	3.10	3.05	3.15	3.14
SOYBEAN MEAL	$/cwt.	5.40	5.30	5.10	4.90	4.85	4.80	4.75	5.01
COTTON SEED MEAL	$/cwt.	5.50	5.40	5.30	5.20	5.00	4.90	4.65	5.14
LINSEED MEAL	$/cwt.	5.50	5.50	5.60	5.40	5.30	5.00	5.00	5.33
ALFALFA HAY	$/ton	39.00	39.00	40.00	37.00	35.50	34.00	30.05	36.36
PRAIRIE HAY	$/ton	28.50	29.00	29.50	28.50	26.50	22.00	22.00	26.57
STOCKER & FEEDER CATTLE		22.00	20.10	21.10	19.90	19.90	18.10	18.30	19.92

APPENDIX TABLE 4 - CONTINUED

ACTUAL PRICES FOR FEEDS AND BEEF

		1953		1954					Average
		NOV.	DEC.	JAN.	FEB.	MAR.	PAR.	MAY	seven months
CORN	$/bu.	1.35	1.43	1.44	1.44	1.44	1.46	1.48	1.43
GRAIN SORGHUM	$/cwt.	2.01	2.06	2.10	2.17	2.23	2.32	2.35	2.18
BARLEY	$/bu.	1.16	1.17	1.21	1.21	1.21	1.19	1.14	1.18
OATS	$/bu.	.78	.81	.81	.81	.80	.82	.78	.80
WHEAT	$/bu.	2.08	2.06	2.08	2.11	2.14	2.14	2.00	2.09
BRAN	$/cwt.	2.45	2.60	2.75	2.75	2.80	3.10	2.75	2.74
SOYBEAN MEAL	$/cwt.	4.20	4.55	4.65	4.75	5.00	5.30	5.00	4.78
COTTONSEED MEAL	$/cwt.	3.65	3.15	3.45	3.55	4.05	4.05	4.30	3.74
LINSEED MEAL	$/cwt.	4.55	4.65	4.75	4.85	4.90	4.90	5.70	4.90
ALFALFA HAY	$/ton	29.00	29.00	29.00	28.00	26.00	26.00	23.50	27.21
PRAIRIE HAY	$/ton	22.00	22.50	22.50	21.00	20.50	20.00	19.50	21.14
STOCKER & FEEDER CATTLE		16.20	16.20	19.00	18.70	18.40	18.80	18.70	18.00

APPENDIX TABLE 4 - CONTINUED

ACTUAL PRICES FOR FEEDS AND BEEF

		1954 NOV.	DEC.	JAN.	FEB.	1955 MAR.	APR.	MAY	Average seven months
CORN	$/bu.	1.45	1.45	1.45	1.43	1.39	1.39	1.45	1.43
GRAIN SORGHUM	$/cwt.	2.10	2.18	2.22	2.22	2.19	2.18	2.21	2.19
BARLEY	$/bu.	1.13	1.14	1.15	1.12	1.08	1.05	1.06	1.10
OATS	$/bu.	.79	.81	.80	.79	.77	.76	.76	.78
WHEAT	$/bu.	2.17	2.19	2.20	2.18	2.19	2.17	2.20	2.19
BRAN	$/cwt.	2.50	2.50	2.50	2.50	2.55	2.50	2.45	2.50
SOYBEAN MEAL	$/cwt.	4.60	4.60	4.60	4.50	4.45	4.70	4.30	4.54
COTTONSEED MEAL	$/cwt.	4.40	4.45	4.40	4.40	4.30	4.20	4.20	4.34
LINSEED MEAL	$/cwt.	4.65	4.70	4.75	4.75	4.70	4.35	4.60	4.64
ALFALFA HAY	$/ton	25.80	26.50	26.00	25.60	23.80	23.40	22.40	24.79
PRAIRIE HAY	$/ton	19.50	19.90	20.10	18.90	17.60	17.30	17.00	18.61
STOCKER & FEEDER CATTLE		18.40	17.50	19.20	19.10	19.60	19.60	17.80	18.74

APPENDIX TABLE 4 - CONTINUED

ACTUAL PRICES FOR FEEDS AND BEEF

		1955				1956			
		NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	Average seven months
CORN	$/bu.	1.24	1.38	1.39	1.29	1.30	1.40	1.48	1.33
GRAIN SORGHUM	$/cwt.	1.76	1.81	1.81	1.82	1.83	1.90	2.03	1.85
BARLEY	$/bu.	.90	.89	.89	.89	.88	.91	.94	.90
OATS	$/bu.	.65	.66	.67	.65	.65	.65	.66	.66
WHEAT	$/bu.	1.97	1.98	1.98	1.97	2.00	2.06	2.02	2.00
BRAN	$/cwt.	2.25	2.25	2.25	2.30	2.30	2.45	2.65	2.35
SOYBEAN MEAL	$/cwt.	3.90	3.85	3.80	3.75	3.70	3.70	3.95	3.81
COTTONSEED MEAL	$/cwt.	3.75	3.70	3.75	3.70	3.65	3.60	3.65	3.69
LINSEED MEAL	$/cwt.	4.40	4.45	4.45	4.35	4.25	4.30	4.30	4.36
ALFALFA HAY	$/ton	23.80	23.50	22.10	22.50	20.50	20.80	21.70	22.13
PRAIRIE HAY	$/ton	18.10	18.70	16.70	17.20	15.60	16.70	17.20	17.17
STOCKER & FEEDER CATTLE		15.80	17.70	15.90	15.60	16.10	16.60	16.60	16.33

APPENDIX TABLE 4 - CONTINUED

ACTUAL PRICES FOR FEEDS AND BEEF

		1956				1957			
		NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	Average seven months
CORN	$/bu.	1.33	1.36						1.35
GRAIN SORGHUM	$/cwt.	2.23	2.27						2.25
BARLEY	$/bu.	1.04	1.09						1.07
OATS	$/bu.	.79	.83			NOT			.81
WHEAT	$/bu.	2.07	2.06						2.07
BRAN	$/cwt.	2.40	2.45						2.43
SOYBEAN MEAL	$/cwt.	3.70	3.70		AVAILABLE				3.70
COTTONSEED MEAL	$/cwt.	3.75	3.75						3.75
LINSEED MEAL	$/cwt.	4.25	4.20						4.23
ALFALFA HAY	$/ton	30.00	31.10						30.55
PRAIRIE HAY	$/ton	24.00	25.10						24.55
STOCKER & FEEDER CATTLE		16.40	15.00						15.70

APPENDIX TABLE 4 - CONCLUDED

ACTUAL PRICES FOR FEEDS AND BEEF

		1957		1958					
		NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	Average seven months
CORN	$/bu.	1.01	1.03	1.03	1.00	1.02	1.07	1.10	1.04
GRAIN SORGHUM	$/cwt.	1.32	1.27	1.46	1.50	1.58	1.65	1.67	1.49
BARLEY	$/bu.	.80	.80	.78	.76	.75	.75	.73	.77
OATS	$/bu.	.60	.61	.59	.57	.58	.61	.61	.60
WHEAT	$/bu.	1.91	1.92	1.91	1.92	1.99	2.02	1.96	1.95
BRAN	$/cwt.	1.95	1.95	1.95	2.10	2.25	2.35	2.35	2.13
SOYBEAN MEAL	$/cwt	3.55	3.50	3.50	3.50	3.60	3.85	3.90	3.63
COTTONSEED MEAL	$/cwt.	3.50	3.55	3.60	3.60	3.65	3.65	3.65	3.60
LINSEED MEAL	$/cwt.	3.95	3.85			3.95	2.70	2.60	3.41
ALFALFA HAY	$/ton	17.00	17.30	16.20	14.86	14.60	14.20	13.20	15.36
PRAIRIE HAY	$/ton	14.50	15.00	12.50	11.00	11.00	11.00	10.00	12.14
STOCKER & FEEDER CATTLE		20.30	21.60	22.50	23.30	24.40	25.30	25.90	23.33

APPENDIX TABLE 5

AVERAGE MONTHLY PRICES FOR TEN YEAR PERIOD STUDIED

		NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY
CORN	$/bu.	1.38	1.45	1.48	1.39	1.46	1.49	1.52
GRAIN SORGHUM	$/cwt.	2.08	2.16	2.22	2.14	2.25	2.29	2.31
BARLEY	$/bu.	1.14	1.18	1.20	1.14	1.17	1.17	1.03
OATS	$/bu.	.82	.85	.89	.82	.84	.84	.83
WHEAT	$/bu.	2.10	2.11	2.14	2.06	2.13	2.14	2.11
BRAN	$/cwt.	2.80	2.84	2.86	2.80	2.90	3.05	3.10
SOYBEAN MEAL	$/cwt.	4.49	4.50	4.59	4.44	4.48	4.56	4.54
COTTONSEED MEAL	$/cwt.	4.37	4.36	4.45	4.37	4.39	4.36	4.34
LINSEED MEAL	$/cwt.	4.63	4.71	4.93	4.90	4.75	4.53	4.61
ALFALFA HAY	$/ton	24.76	25.18	24.76	23.45	22.54	22.60	21.65
PRAIRIE HAY	$/ton	17.34	18.48	17.12	16.37	18.61	15.29	15.52
STOCKER & FEEDER CATTLE		21.12	20.73	19.00	19.71	22.96	23.39	23.56

APPENDIX TABLE 6

PRICE RATIOS CORRESPONDING TO VARIOUS LOTS OF STEERS STUDIED

LOT NUMBER	PRICE RATIO NUMBER	PRICE RATIO (Dollars/lb.)
1	7	.020/.005
2	7	.020/.005
3	7	.020/.005
4	7	.020/.005
5	7	.020/.005
11	1	.020/.012
12	1	.020/.012
13	1	.020/.012
14	1	.020/.012
20	7	.020/.005
21	7	.020/.005
22	2	.021/.013
23	2	.021/.013
40	3	.022/.014
41	3	.022/.014
42	2	.021/.013
43	2	.021/.013
50	2	.021/.013
51	1	.020/.012
52	2	.021/.013
53	3	.022/.014
60	3	.022/.014
62	3	.022/.014
62A	1	.020/.012
70	7	.020/.005
71	7	.020/.005
72	7	.020/.005
80	2	.021/.013
81	7	.020/.005
82	7	.020/.005

APPENDIX TABLE 6 - CONCLUDED

PRICE RATIOS CORRESPONDING TO VARIOUS LOTS OF STEERS STUDIED

LOT NUMBER	PRICE RATIO NUMBER	PRICE RATIO (Dollars/lb.)
90	1	.020/.012
91	7	.020/.005
101	7	.020/.005
103	3	.022/.014
104	5	.024/.016
106	6	.025/.017
107	4	.023/.015
108	5	.024/.016
109	5	.024/.016

APPENDIX II

LEAST SQUARES DETERMINIATION OF REGRESSION COEFFICIENTS

From the least squares theory, the two partial regression coefficients are calculated by a pair of simultaneous normal equations,

$$x_1^2 b_{y1.2} + x_1 x_2 b_{y2.1} = x_1 y$$

$$x_1 x_2 b_{y1.2} + x_2^2 b_{y2.1} = x_2 y$$

$$b_{y1.2} = \frac{(x_2^2)(x_1 y) - (x_1 x_2)(x_2 y)}{(x_1^2)(x_2^2) - (x_1 x_2)^2}$$

$$b_{y2.1} = \frac{(x_1^2)(x_2 y) - (x_1 x_2)(x_1 y)}{(x_1^2)(x_2^2) - (x_1 x_2)^2}$$

Solution of these simultaneous normal equations yielded the following correlation matrix:

$$\begin{matrix} 1 & -.4304 & .8674 \\ -.4304 & 1 & -.4501 \\ .8674 & -.4501 & 1 \end{matrix}$$

and respectively the following inverse of the correlation matrix:

$$\begin{matrix} 1.2273 & .5282 \\ .5282 & 1.2273 \end{matrix}$$

To derive the specific values of the partial regression coefficients, a Table of Cij is set up as:

i	1	j2	x_iy
1	.0156	.0061	14.6429
2	.0061	.0128	-8.3545
b_j	.1175	-.0176	

Reading directly from this table, the respective values for the partial regression coefficients are:

b_1 = .1775

b_2 = -.0176

The value of the constant term on the Y axis intercept point equals 1.2503. Substituting in the original regression equation we get the following specific multiple linear regression equation as:

$Y = 1.2503 + .1775 X_1 - .0176 X_2$, where $X_1 = (x_1 - \bar{x}_1)$ and $X_2 = (x_2 - \bar{x}_2)$.

An analysis of variance for multiple linear regression gave the following:

Source	df	SS	Ms	F
Due to regression	2	2.7462	1.3731	44.01**
Deviations about Regression	27	.8656	.0321	
Total	29	3.6118		

These values were calculated as:

SS Due to Regression

$$R^2 \quad yi^2 = b_1 \quad x_1y + b_2 \quad x_2y$$

$$= 2.7462$$

Total SS = $\quad yi^2 = 3.6118$

SS Deviations about Regression

$$yi^2 - R^2 \quad yi^2 = 3.6118 - 2.7462 = .8656$$

$$\text{where } R^2 = \frac{R^2 \quad yi^2}{yi^2} = \frac{2.7462}{3.6118} = .7603$$

The significant values therefore, for the variance connected for years, are found from the above calculations as:

R^2 = Coefficient of Determination = .7603

R = Multiple Correlation Coefficient = .8720

The variance of the estimate $S^2_{y.12} = \frac{.8656}{27} = .0321$.

Another analysis of variance for multiple linear regression was run giving the following results for unconnected years data:

R^2 (Uncorrected for years) = .8358

By substracting the R^2 obtained on an analysis of variance uncorrected for years from an analysis of variance R^2 corrected for years, we find the difference Q = .0755:

R^2 (uncorrected for years) = .8358

R^2 (corrected for years) = .7603

.0755 or 7.55% accountable

for years. To test the significance of years in our statistical analysis, an analysis of variance table can be set up as follows illustrating the influence of years on the rate of gain.

APPENDIX TABLE 7

STATISTICAL ANALYSIS OF VARIANCE

MULTIPLE REGRESSION ANALYSIS

SOURCES	DEGREES OF FREEDOM	SQUARES	MEAN SQUARE	F
Years	9	.0755	.0084	1.38157 ns
Within Years	2	.7603	.3802	
About Regression	27	.1642	.00608	
	38	1.0000		

The significance of the coefficient -.0176 was tested by use of the "t" test, the formula for which is as follows:[35]

$$\text{"t"} = \frac{\bar{x} -}{s/\ \ n} \quad , \text{ where}$$

$\bar{x}$ is the sample mean as the sum of the observations successively divided by the number sampled. In this case 372.71 ÷ 39 = 9.566.

is the estimated sample mean in this case -.0176.

s/ n is the sample standard error. It is found by first determining the square root of the deviations about regression and dividing by the sample number. In this case 372.71 = 19.31 ÷ 39 = .4951.

Hence, "t" = 9.566 + .0176 ÷ .4951 or 19.3382. By comparing the distribution of "t", we find the probability is less than .001 of a "t" larger or smaller than 3.551.

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[35] Snedecor, *op. cit.*, p. 46.

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ECONOMIC IMPLICATIONS OF ROUGHAGE AND GRAIN SUBSTITUTION IN BEEF CATTLE WINTERING RATIONS

by

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AN ABSTRACT OF A MASTER'S THESIS

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Cattle feeders in the Great Plains area have expressed a need to determine empirically the economic relationship of roughage and grain imputs in wintering beef steers. While the source of roughage and grain is abundant in Kansas, there is little knowledge of the economic relationship with regard to certain physical input-output relationships. In order to determine the maximum efficiency in wintering rations, it is necessary to determine the production function to later be compared with price relationships.

Research in this study was based on data from ten years of wintering experiments published in Feeders' Day Progress Reports from Kansas State University and from feeding records. This data were used in a regression analysis of average daily gain. Statistical tests indicated no significant year to year variation. The objectives of the study were to derive (1) the production function, (2) the iso-product relationships, (3) the marginal rates of substitution, and (4) a least cost feed combination. A graphic analysis was attempted to determine input-output relationships associated with different weight levels but this produced apparent inconclusive results.

A mathematical regression equation was derived for gain per head per day. Using a quadratic equation, an iso-product curve was computed for 1 pound daily gain, indicating diminishing marginal rates of substitution. Physically it was found that grain will substitute for roughage in a beef wintering ration within the boundaries of the data observed.

By fitting the price ratio existing during the time studied to the iso-product curve, a minimum cost combination was determined. Since none of the rations studied contained grain alone, the data indicates a combination of hay and grain is economically feasible. It also is logical from a physiological standpoint.